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SECURITY INFORMATION

SECRET

SUPPLEMENT TO

TWENTY-NINTH

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER COMPANY

ON

105 MM. BATTALION ANTI-TANK PROJECT

UNDER

Contract No. DA-33-019-ORD-33

ORDNANCE DEPARTMENT PROJECTS

TS4-4020—WEAPONS AND ACCESSORIES

TM1-1540—AMMUNITION

COPY No. 1

THE FIRESTONE TIRE & RUBBER COMPANY
Defense Research Division
Akron, Ohio

DECEMBER 1952

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SUPPLEMENT TO

TWENTY-NINTH

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER CO.

ON

105 MM BATTALION ANTI-TANK PROJECT

Contract No.
DA-33-019-ORD-33 (Negotiated)
RAD ORDTS 1-12383

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THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio

DECEMBER, 1952

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ABSTRACT

Three lots of serrated liners were tested for penetration into mild steel at various spin rates. The liner designs are illustrated, the inspection and penetration data are presented, and the test results are discussed.

The correlation between performance and external flute design is summarized to date.

Dynamic firing tests with T138E73 projectiles, incorporating DRD393 copper liners, were conducted and the data are presented.

Serrated Liners

Three sets of serrated liners and two sets of controls have been tested for penetration into mild steel, at various spin rates and at a standoff of 7.50 inches.

The liner designs, DRD78-2 (5-degree index angle), DRD393 item 1 and DRD393 item 2 are shown in Figures 1 and 2. Figures 3 and 4 show the DRB2 cone from which the DRD78-2 cones were pressed and the DRB398 cone from which the DRD 393 cones were pressed. The inspection data are shown in Tables I, III and V and the penetration data are shown in Tables II, IV and VI. Spin rate versus penetration curves are shown in Figures 5 to 9.

DRD78-2 (5-degree Index Angle) Liners

The DRD78-2 liners reported here have 16 flutes on both the internal and external surfaces. They differ from the DRD78-2 cones, whose performance was reported in the Supplement to the Thirteenth Progress Report, in that the index angle between the inside and outside flutes is a nominal 5° instead of 2° as shown in Figure 1. The actual index angles, measured on these two series of DRD78-2 cones, were $1^{\circ}8'$ and $4^{\circ}26'$. The average penetration at the peak of the penetration curve is 14.8 inches and occurs at ~85 rev/sec. This result is considerably different from the earlier one in which the best performance was 17.0 inches at +5 rev/sec and demonstrates the very important effect of the index angle. These data are in close agreement with similar tests on 57mm cones reported by Dr. Emerson Pugh and R. J. Eichelberger (C.I.T.-ORD-R26). Additional tests with other index angles are planned.

All rounds of this type were tested in DRC15 type penetration assemblies. (Fig. 5, Twenty-Fourth Progress Report).

DRD393 Liners

The DRD393 cones have 50 flutes on the external surface only. The two series differ only in the depth of fluting. The DRD393 item 1 cones have flutes .0149 in. deep at a datum .484 in. above the base. The best average penetration is 18.3 in. at 60 rev/sec (Fig. 7). The penetration of this cone is not reduced by the use of DRC314 HW9 tees (in place of the standard nose rings) at 45 rev/sec, nor by DRC314 HW11 tees at 60 rev/sec. A description of these tees and their effect upon the performance of DRB 398 cones may be found in the Twenty-Sixth and Twenty-Seventh Progress Reports.

The DRD393 item 2 cones have flutes .0129 in. deep at a datum .484 in. above the base. The best average penetration is 20.0 in. at 52 rev/sec (Fig. 8). Although the DRC314 HW11 tee does reduce the penetration of this cone slightly even at 45 rev/sec the penetration of 18.5 in. permitted is satisfactory.

A standard penetration curve for the DRB398 blank is shown for comparison in Fig. 9.

All penetration assemblies in the DRD 393 series were of the DRC376 type. (Fig. 4, Twenty-Fourth Progress Report). Where noted, tees replaced the standard nose rings.

Correlation of Externally Fluted Liner Performance

A correlation between penetration behavior and design parameters for externally fluted cones was presented in the Supplement to the Sixteenth Progress

Report. This correlation was revised by the inclusion of additional data in the Supplement to the Twenty-Second Progress Report. Additional data now permits a further extension of this correlation.

Table VII shows the design parameters and penetration behavior for all cones of the DRB2 type; Table VIII for the cones of the DRB398 type. The calculations for the correlation factor f (N) are summarized in Table IX. Figure 10 is a plot of the correlation. As additional data become available they will be included in later additions or revisions to this correlation.

Dynamic Penetration Tests With Serrated Liners

Ten DRD393 item 1 cones were assembled in T138E73 projectiles and tested by firing against armor plate at Aberdeen Proving Ground. Table X is a modification chart for the T138E73 projectile. Inspection data for these cones are shown in Table III and static penetration data for similar cones in Table IV and Figure 7. The tees used were DRC314 HW9. The rounds were fired from a T137E1 rifle. Standard T137E57 projectiles (with smooth cones) were fired for comparison. The data are shown in Table XI.

At 58 rev/sec (1600 ft/sec from a 1-80 tube) the average penetration of the DRD393 item 1 cones was 10.2 in. compared with 8.1 in. for the smooth cone. At 40 rev/sec (1640 ft/sec from a 1-120 tube) the average penetration of the DRD 393 item 1 cones was 8.00 in. compared with 7.5 in. for the smooth cones.

While it is true that in each test the fluted cones appeared to be slightly better than the smooth control cones, their performance was far below expectation. Based upon the static tests shown in Fig. 7, and making allowance for a 15 percent reduction in penetration because of the use of armor plate in the dynamic tests, penetrations of 13.0 in. at 40 rev/sec and 13.5 in. at 60 rev/sec were anticipated. Because of the relatively poor performance of these rounds the three remaining rounds were fired statically at the Ballistic Research Laboratories penetration chamber at 60 rev/sec. The target material was classed as "green" armor which has been shown to have penetration characteristics similar to mild steel. The average penetration for the three static rounds was 12.6 in. which, when reduced by 15 percent, is approximately equal to 10.7 in. This is comparable to the penetration measured dynamicall at 58 rev/sec. No reason is known for the poor performance of these rounds and therefore additional tests are planned.

Future Program

1. Serrated Liners

   (a) DRD78 cones modified by a change of the index angle. Index angles of 6.50°, 8.0° and 20° are planned.

   (b) DRD393 item 2 cones. Static and dynamic tests in T138E73 assemblies.

2. Double Body Projectiles

   (a) Firing tests with test slugs having tapered bearings and ball bearings to determine comparative efficiency.

   (b) Test double body projectiles with DRC389 bearings for spin rate and accuracy.

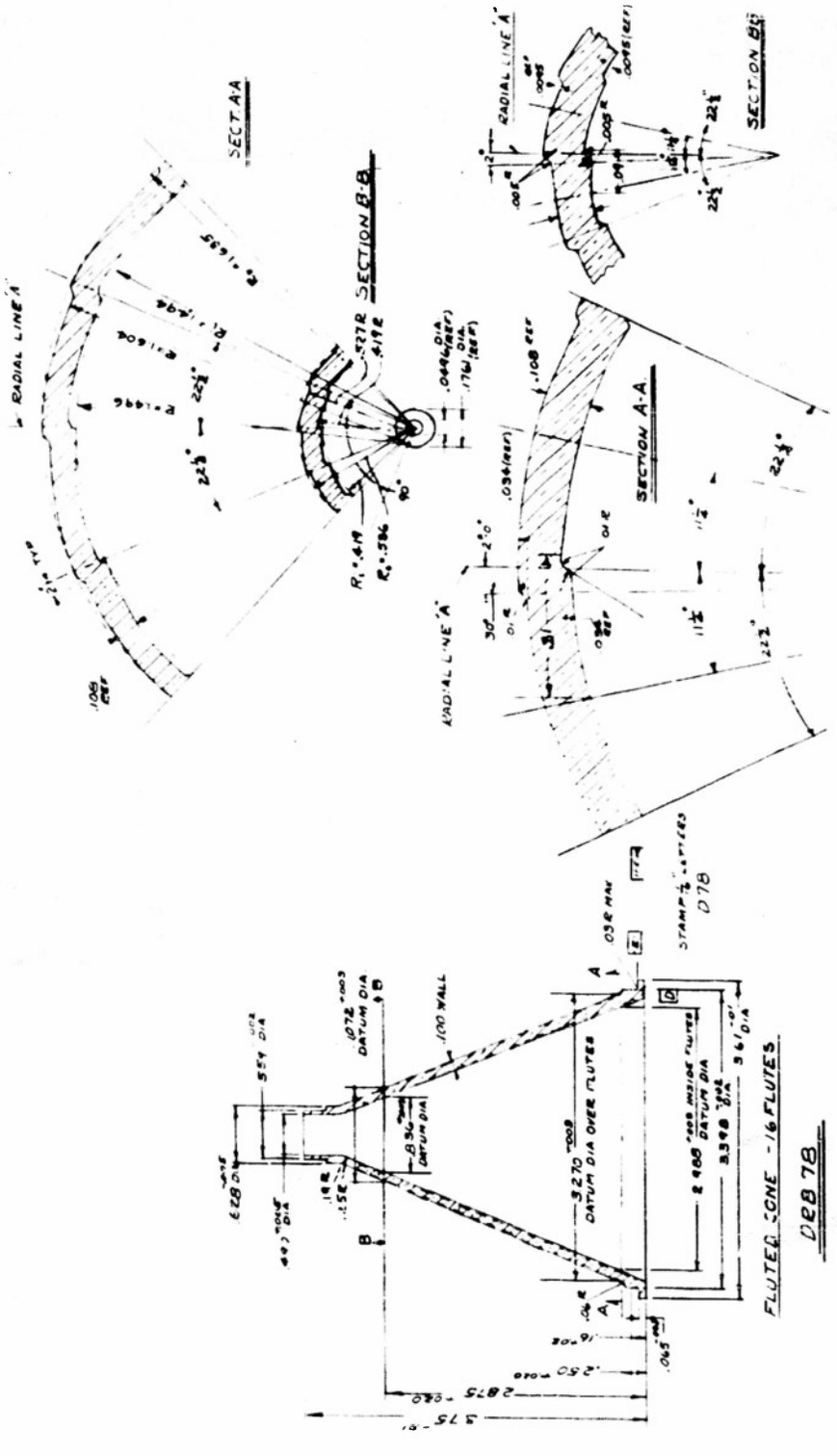
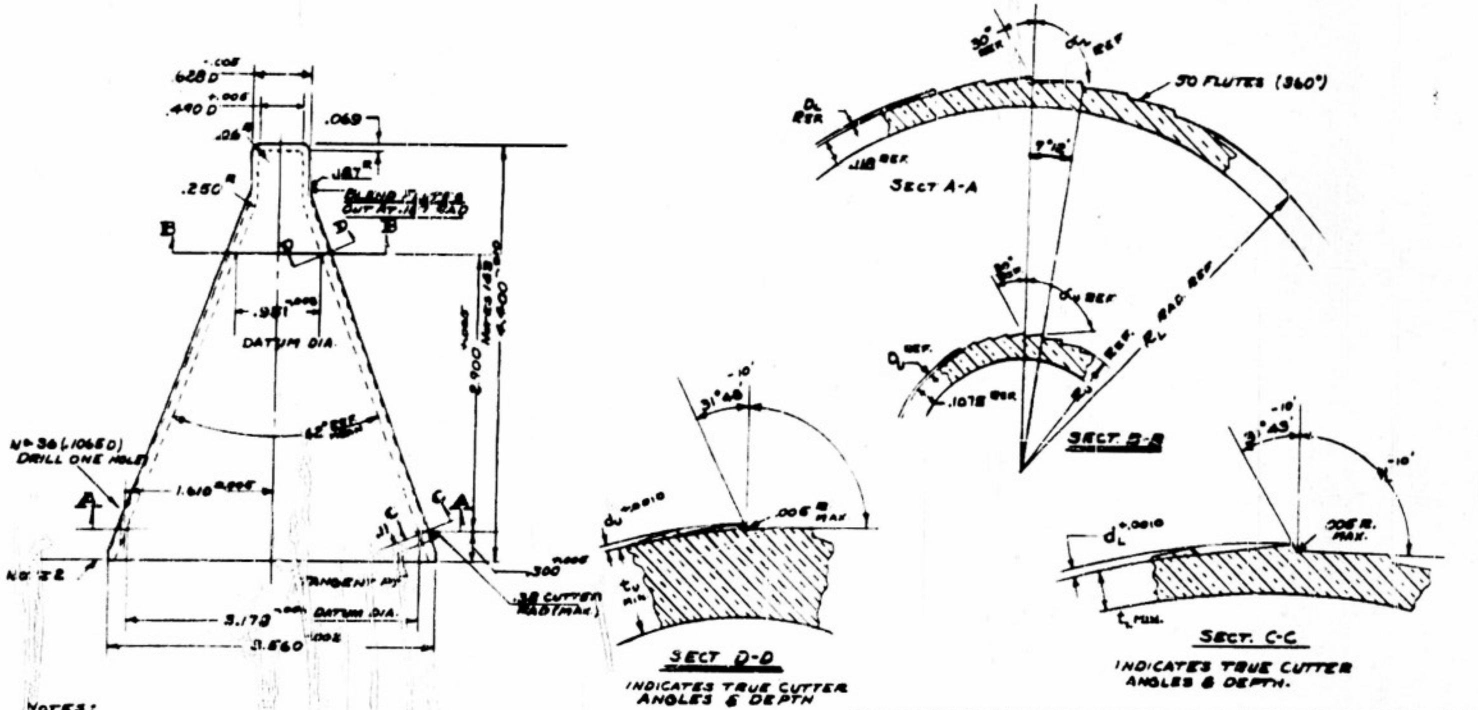


Fig. 1. DRD78.2 Liner Design.
5-degree Index Angle.



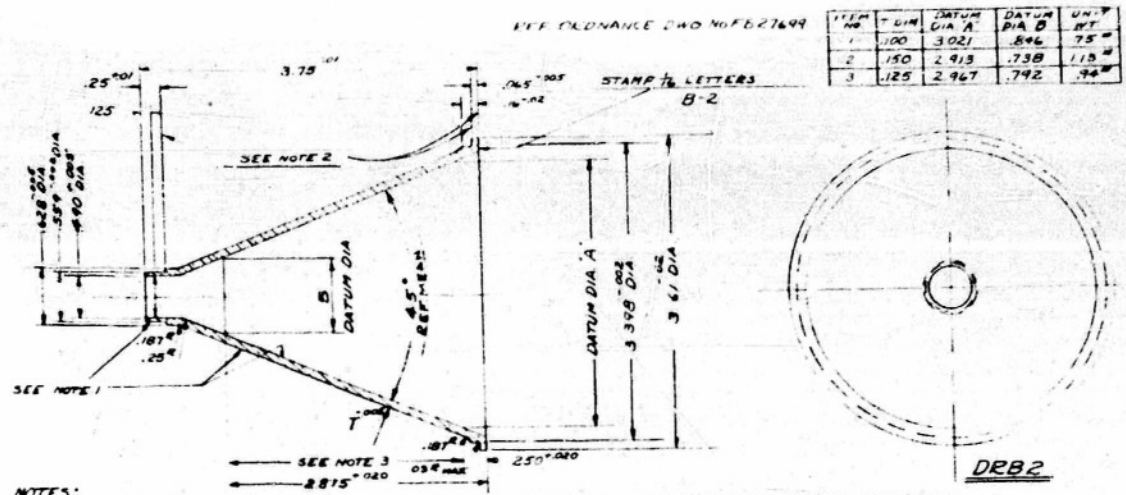
NOTES:

1. ALL FLUTE CRESTS TO BE CONCENTRIC WITHIN .003 T.I.R. WITH RESPECT TO 3.560 REGISTER DIA.
2. INDICATED SURFACE TO BE PERPENDICULAR WITH ℄ OF PART WITHIN .003 TOTAL INDICATOR READING.
3. IN THIS REGION VARIATION IN STRAIGHTNESS OR THICKNESS OF WALL SHALL NOT EXCEED .003 IN ANY AXIAL PLANE OR IN ANY TRANSVERSE PLANE WALL THICKNESS VARIATION SHALL NOT EXCEED .001 AT CRESTS OR ROOTS OF FLUTES
4. FINISH

ITEM	D_L	d_L	R_L	t_L	d_L/R_L	α_L	γ_L	D_U	d_U	R_U	t_U	d_U/R_U	α_U	γ_U
1	.016	.0149	1.707	.095	[illegible]	[illegible]	[illegible]	[illegible]	.0051	[illegible]	.095	[illegible]	[illegible]	[illegible]
2	.014	.0131	1.705	.096	.00768	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.096	.00772	[illegible]	[illegible]
3	.012	.0112	1.704	.096	.006572	90° 10'	[illegible]	.0041	.0038	[illegible]	.096	[illegible]	90° 10'	[illegible]

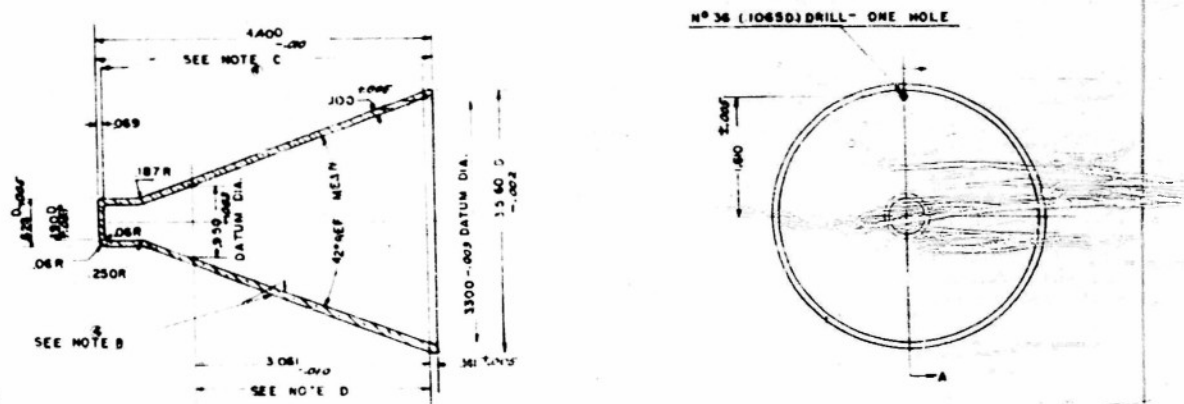
CONE SERRATED 42°, 50 FLUTES
DRD 393-1

Fig. 2. DRD393 Liner Design.
Items 1 and 2.



NOTES:
1 ALL INDICATED SURFACES TO BE CONCENTRIC WITHIN .003 T.I.R WITH RESPECT TO 3.398 DIA REGISTER.
2 ALL INDICATED SURFACES TO BE FLAT & PARALLEL TO WITHIN .005 T.I.R & PERPENDICULAR TO ℄ OF PART.
3 IN THIS REGION VARIATION IN STRAIGHTNESS OR THICKNESS OF WALL SHALL NOT EXCEED .009 IN ANY AXIAL PLANE; WALL THICKNESS IN ANY TRANSVERSE PLANE SHALL NOT EXCEED .001 VAR
4 FINISH ✓ UNLESS OTHERWISE SPECIFIED

Fig. 3. DRB2 Conical Liner.
From Which DRD78-2 Liners Were Pressed.



NOTE

A FINISH ✓

B ALL INDICATED SURFACES MUST BE CONCENTRIC WITHIN .003 T.I.R WITH RESPECT TO 3.580 REGISTER DIA.

C ALL INDICATED SURFACES MUST BE FLAT & PARALLEL WITHIN .005 T.I.R & PERPENDICULAR TO CENTER LINE OF PART.

D. IN THIS REGION VARIATION IN STRAIGHTNESS OR THICKNESS OF WALL SHALL NOT EXCEED .006 IN ANY AXIAL PLANE. VARIATION OF WALL THICKNESS IN ANY TRANSVERSE PLANE SHALL NOT EXCEED .002

E. PREFERRED MATERIAL: OXYGEN FREE, NO RESIDUAL DEOXIDANTS, COPPER, ALTERNATIVE MATERIAL ELECTROLYTIC, TOUGH PITCH, COPPER.

Fig. 4. DRB398 Conical Liner.
From Which DRD393 Liners Were Pressed.

Table I

Inspection Data

For DRD78-2 (5° Index Angle) Liners

Liner No.	Avg. Outside Flute Depth (in.)		Avg. Inside Flute Depth (in.)		Avg. Wall Thickness (in.)		Concentricity (in.) [2]	
	Lower [1] Datum	Upper Datum	Lower [1] Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum
DRD-78-2	.0294	.0088	.0294	.0088	.1000	.1000	.0030	.0030
C16-115	.0267	.0083	.0330	.0121	.1258	.1236	.0030	.0040
C16-116	.0265	.0080	.0310	.0122	.1268	.1281	.0050	.0040
C16-117	.0272	.0082	.0336	.0112	.1290	.1260	.0060	.0040
C16-118	.0266	.0080	.0347	.0113	.1281	.1273	.0020	.0040
C16-119	.0274	.0080	.0335	.0115	.1275	.1276	.0020	.0040
C16-120	.0268	.0080	.0338	.0112	.1273	.1266	.0030	.0050
C16-122	.0266	.0079	.0334	.0121	.1278	.1261	.0025	.0030
C16-123	.0266	.0078	.0339	.0121	.1285	.1263	.0050	.0050
C16-124	.0271	.0083	.0341	.0136	.1300	.1294	.0070	.0030
C16-125	.0270	.0083	.0328	.0115	.1282	.1285	.0060	.0060
C16-126	.0271	.0076	.0336	.0132	.1280	.1266	.0040	.0030
C16-127	.0267	.0080	.0358	.0114	.1242	.1231	.0040	.0070
C16-128	.0272	.0081	.0332	.0124	.1259	.1244	.0050	.0040
C16-129	.0267	.0082	.0352	.0125	.1282	.1275	.0040	.0050
C16-130	.0263	.0081	.0343	.0127	.1286	.1295	.0060	.0030
C16-132	.0272	.0078	.0331	.0129	.1296	.1275	.0040	.0060
C16-133	.0271	.0082	.0334	.0133	.1288	.1295	.0050	.0040
C16-136	.0271	.0077	.0346	.0127	.1251	.1264	.0040	.0040
C16-137	.0270	.0077	.0334	.0130	.1280	.1290	.0100	.0060
C16-138	.0268	.0076	.0336	.0132	.1264	.1275	.0060	.0050
C16-139 [3]	.0277	.0083	.0353	.0129	.1279	.1279	.0040	.0030
AVERAGE	.0269	.0080	.0338	.0123	.1276	.1271	.0046	.0044
STD. DEV.	±.0003	±.0002	±.0010	±.0007	±.0014	±.0017	±.0018	±.0008

NOTES:

1. Lower datum is .480 inch above the base; upper datum 2.875 inches above base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for sectioning and display.

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Table II
Penetration Data
for DRD78-2 (5° Index Angle) Liners

Round No.	Lbs. Comp B	Rev/Sec	Penetration inches M.S.	Max. Spread(in.)	Std. Dev. (in.)
C16-125	2.54	-120	10.81		
C16-126	2.52	"	11.69		
C16-127	2.54	"	9.88		
			Avg. 10.79	1.81	±.91
C16-133	2.54	-105	13.25		
C16-136	2.56	"	13.44		
C16-137	2.54	"	12.25		
			Avg. 12.98	1.19	±.64
C16-122	2.54	-90	14.69		
C16-123	2.54	"	14.25		
C16-124	2.54	"	14.56		
C16-138	2.52	"	14.94		
			Avg. 14.61	0.69	±.30
C16-129	2.56	-75	14.88		
C16-130	2.54	"	14.75		
C16-132	2.54	"	13.75		
			Avg. 14.46	1.13	±.62
C16-116	2.52	-60	11.94		
C16-117	2.52	"	11.50		
C16-128	2.56	"	10.06		
			Avg. 11.17	1.88	±.99
C16-118	2.52	0	6.12		
C16-115	2.52	"	6.62		
			Avg. 6.37	--	--
C16-119	2.54	+60	3.88		
C16-120	2.54	"	5.00		
			Avg. 4.44	--	--
Controls					
FS618	2.52	0	18.69		
FS623	2.50	"	18.50		
FS624	2.52	"	19.12		
FS625	2.52	"	17.81		
FS626	2.54	"	17.18		
			Avg. 18.26	1.94	±.77
FS617	2.54	-90	7.44		
FS619	2.54	"	7.62		
FS620	2.54	"	6.94		
FS621	2.54	"	10.94		
FS622	2.54	"	7.75		
			Avg. 8.14	4.00	±1.60

Notes:
1. Cones assembled in DRC15-8 bodies, plugs and rings.
2. Rounds loaded at Ravenna Arsenal, BAT Lot No. 19 with Composition B Holston Lot 3-126.
3. All rounds were fired at a standoff of 7.5 inches.

Table III
Inspection Data
For DRD393 Item 1, Lot No. 1 Liners

Liner No	Avg Flute Depth (in)		Avg Wall Thickness (in)		Concentricity (in.)[2]	
	Lower[1] Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum
DRD393 item 1	.0143	.0051	.1096	.1004	.0030	.0030
P50-50	.0150	.0040	.1130	.1020	.0020	.0050
P50-51	.0152	.0042	.1109	.1000	.0030	.0030
P50-52	.0149	.0039	.1101	.0966	.0050	.0050
P50-53	.0149	.0039	.1121	.0958	.0060	.0050
P50-54	.0150	.0030	.1060	.0905	.0030	.0030
P50-55	.0149	.0039	.1098	.0945	.0025	.0040
P50-56	.0146	.0040	.1128	.0956	.0040	.0050
P50-57	.0147	.0033	.1115	.0943	.0020	.0010
P50-58	.0150	.0033	.1131	.0931	.0020	.0040
P50-59	.0150	.0031	.1099	.0930	.0040	.0020
AVERAGE	.0149	.0037	.1109	.0955	.0034	.0037
STD. DEV.	±.0002	±.0004	±.0021	±.0034	±.0014	±.0014

NOTES:
1. Lower datum is .484 inch above the base; upper datum 3.200 inches above base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the registe. diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.

Table IV
Penetration Data
For DRD393 Item 1, Lot No. 1 Liners

Round No	Lbs Comp B	Rev/Sec	Penetration (inches MS)	Max Spread (in)	Std Dev (in)
P50-40	2.60	+10	11.75		
P50-41	2.62	"	12.44		
P50-42	2.60	"	12.38		
			Avg. 12.19	0.69	±0.38
P50-10	2.60	+45	20.38		
P50-11	2.64	"	15.38		
P50-12	2.62	"	18.69		
P50-13	2.58	"	12.25		
P50-43	2.62	"	12.94		
P50-44	2.64	"	11.38		
			Avg. 14.94	8.80	±3.84
P50-14	2.62	+60	18.25		
P50-15	2.60	"	18.44		
P50-16	2.64	"	18.12		
			Avg. 18.27	0.32	±0.16
P50-17	2.62	+75	16.50		
P50-18	2.60	"	16.62		
P50-19	2.62	"	17.44		
			Avg. 16.85	0.94	±0.41
with DRC 314 HW9 (20° chamfer) tees with caps.					
P50-45	2.62	+45	13.62		
P50-46	2.62	"	15.62		
P50-47	2.64	"	17.06		
P50-48	2.64	"	11.75		
P50-49	2.62	"	15.68		
			Avg. 15.75	5.00	±1.15
with DRC 314 HW11 tees with caps.					
P50-60	2.62	+60	18.94		
P50-61	2.62	"	18.94		
P50-62	2.62	"	18.50		
P50-63	2.62	"	17.18		
P50-64	2.62	"	18.06		
			Avg. 18.31	1.76	±0.74

Notes:
1. Assembled with DRC 376 bodies, plugs and rings except P50-45 to 49 which had tees DRC 314 HW9 instead of rings and P50-60 to 64 which had tees ORC 314 HW11.
2. Loaded at Ravenna Arsenal, BAT Lot No. 18, with Composition B, Holston Lot 3-126.
3. All rounds were fired at Erie Ordnance Depot. A standoff of 2.50 inches was used.
4. Above lot of cones not inspected - assumed to be the same as Lot No. 1 Table III
5. Rounds P50-60 to P50-64 had DRC 376 bodies and plugs, no base cleaned cavity.
6. Rounds P50-60 to P50-64 were loaded at Ravenna Arsenal, BAT Lot No. 20, with Comp. B of Holston Lot 3-126.

Table V
Inspection Data
For DRD393 Item 2 Liners

Liner No.	Avg. Flute Depth (in.)		Avg Wall Thickness (in)		Concentricity (in.)[2]	
	Lower[1] Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum
DRD393 item	.0125	.0045	.1078	.0998	.0030	.0030
P50-81	.0131	.0051	.1068	.0935	.0020	.0040
P50-82	.0130	.0050	.1045	.0933	.0080	.0150
P50-83	.0129	.0050	.1046	.0953	.0030	.0050
P50-84	.0129	.0047	.1035	.0950	.0030	.0030
P50-85	.0127	.0048	.1035	.0945	.0030	.0040
P50-86	.0129	.0049	.1050	.0948	.0020	.0030
P50-87	.0129	.0050	.1050	.0953	.0020	.0040
P50-88	.0127	.0047	.1065	.0944	.0030	.0030
P50-89	.0129	.0048	.1055	.0955	.0030	.0020
P50-90	.0125	.0047	.1063	.0960	.0060	.0130
P50-91	.0128	.0049	.1065	.0945	.0030	.0030
P50-92	.0127	.0049	.1055	.0930	.0020	.0030
P50-93	.0127	.0047	.1038	.0948	.0030	.0050
P50-94	.0128	.0049	.1055	.0948	.0035	.0040
P50-95	.0129	.0048	.1043	.0940	.0040	.0060
P50-96	.0127	.0048	.1030	.0928	.0040	.0060
P50-97	.0128	.0050	.1053	.0953	.0045	.0060
P50-98	.0130	.0050	.1059	.0940	.0050	.0050
P50-99	.0129	.0049	.1015	.0935	.0030	.0020
P50-100	.0130	.0049	.1044	.0935	.0030	.0030
P50-101	.0129	.0050	.1043	.0943	.0020	.0070
P50-102	.0130	---	.1055	.0925	.0030	.0030
P50-103	.0128	.0048	.1064	.0963	.0020	.0050
P50-104	.0130	.0050	.1045	.0918	.0020	.0030
P50-105	.0130	.0050	.1053	.0935	.0030	.0050
P50-106	.0128	.0050	.1045	.0945	.0070	.0100
P50-107	.0128	.0050	.1023	.0925	.0030	.0040
P50-108	.0127	.0050	.1043	.0943	.0020	.0060
P50-109	.0128	.0049	.1050	.0953	.0060	.0050
P50-110	.0129	.0050	.1045	.0938	.0040	.0060
P50-111	.0129	.0050	.1074	.0953	.0030	.0030
P50-112	.0128	.0050	.1063	.0953	.0040	.0025
P50-113	.0130	.0049	.1043	.0940	.0020	.0020
P50-114	.0127	.0050	.1046	.0943	.0030	.0050
P50-115	.0125	.0050	.1068	.0955	.0050	.0050
P50-116	.0128	.0049	.1051	.0933	.0020	.0050
P50-117	.0129	.0051	.1040	.0940	.0020	.0030
P50-118	.0129	.0050	.1046	.0940	.0020	.0040
P50-119	.0130	.0050	.1043	.0923	.0020	.0130
P50-120	.0128	.0050	.1050	.0950	.0030	.0050
P50-121	.0129	.0050	.1051	.0953	.0030	.0040
P50-122	.0130	.0050	.1036	.0928	.0020	.0040
P50-123	.0129	.0050	.1040	.0930	.0070	.0020
P50-124	.0128	.0049	.1059	.0983	.0030	.0020
P50-125	.0129	.0050	.1053	.0945	.0020	.0035
P50-126	.0129	.0050	.1061	.0953	.0020	.0015
P50-127	.0126	.0049	.1061	.0945	.0030	.0070
P50-128	.0128	.0050	.1065	.0946	.0020	.0050
P50-129	.0130	.0050	.1030	.0935	.0030	.0040
P50-130	.0129	.0050	.1048	.0933	.0020	.0060
P50-131	.0128	.0050	.1039	.0925	.0020	.0020
AVERAGE	.0129	.0049	.1049	.0942	.0032	.0047
STD. DEV.	±.0001	±.0001	±.0011	±.0012	±.0014	±.0027

Notes:

1. Lower datum is .484 inch above the base; upper datum 3.200 inches above base
2. The indicated measurement at each datum is the total indicated runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.

Table VI
Penetration Data
For DRD393 Item 2 Liners

Round No.	Lbs. Comp B	Rev/Sec	Penetration (inches M.S.)	Max. Spread (in.)	Std. Dev. (in.)
P50-94	2.60	+15	11.69		
P50-95	2.62	"	9.75		
P50-96	2.60	"	12.75		
			Avg. 11.40	3.00	±1.52
P50-90	2.60	+30	18.50		
P50-91	2.58	"	16.75		
P50-92	2.60	"	14.00		
P50-97	2.60	"	16.81		
			Avg. 16.52	4.50	±1.86
P50-87	2.56	+45	19.50		
P50-88	2.60	"	20.31		
P50-89	2.60	"	19.75		
P50-98	2.60	"	20.69		
P50-99	2.62	"	18.56		
			Avg. 19.76	2.13	±0.82
P50-84	2.50	+60	19.18		
P50-85	2.60	"	19.25		
P50-86	2.58	"	19.56		
P50-100	2.62	"	20.12		
P50-101	2.66	"	19.56		
			Avg. 19.53	0.94	±0.37
P50-81	2.58	+75	15.88		
P50-82	2.58	"	17.06		
P50-83	2.58	"	16.25		
			Avg. 16.40	1.18	±0.60
P50-106	2.70	+45	18.56		
P50-107	2.66	"	19.69		
P50-108	2.68	"	18.12		
P50-109	2.70	"	18.12		
P50-110	2.72	"	18.06		
			Avg. 18.51	1.63	±0.69
Controls					
FS856	2.58	0	21.00		
FS857	2.58	"	18.94		
FS858	2.60	"	22.18		
FS859	2.58	"	19.38		
FS860	2.58	"	19.38		
			Avg. 20.18	3.24	±1.37

Notes:
1. Cones assembled in DRC376 test bodies, base plugs and either DRC376 nose rings or DRC314 HW11 tees.
2. All rounds were fired at a standoff of 7.5 inches.
3. Rounds loaded at Ravenna Arsenal, BAT Lot No. 22 with Composition B, Holston Lot 3-126.
4. FS856 to 860 are control rounds containing DRB398 cones.

Table VII
Summary of Serrated Liner Performance
DRB2 Type Cone (See Fig. 3.)

DRB2 type cone, machined from copper bar, envelope of flute crests for externally fluted cones identical with external surface of DRB2 cone, inside diameter varied as required for desired wall thickness. Except where noted wall thickness is essentially constant over entire cone. Flute depth varies linearly from indicated depth to zero at the theoretical APEX of the cone generated by the flute crests. Radius to outside surface at datum for depth and thickness is 1.5216 inches.

Drawing No.	Number of Flutes[1]	Wall Thickness (in.)	Flute Depth (in.)	γ_o[2]	P_γ	Remarks
DRD263	4CP	.1564	.0614	0	8.0	Ext. Flutes Only
DRD17-6	16F	.1490	.0246	+15	16.0	"
DRD32-3	16C	.0990	.0248	+35	8.5	"
DRD34-3	16F	.1495	.0624	+55	9.6	"
DRD33-3	36C	.1486	.0164	+15	15.2	"
DRD35-3	36F	.1493	.0171	+15	15.5	"
DRD161-1	36F	.0964	.0129	+35	16.9	"
DRD162-2	45F	.0990	.0112	+40	16.0	"
DRD63-3	60F	.0984	.0162	+65	14.0	"
DRD63-3 [3]	60F	.1480	.0168	+25	15.3	"
DRD254 No. 1	100F	.1517	.0422	+20	15.0	"
DRD78-2	16CP	.0967	.0270 (Int) .0281 (Ext)	+5	18.2	Matching Flutes Index Angle=1° 8'
DRD78-2	16CP	.1276	.0338 (Int) .0267 (Ext)	-85	14.8	" " =4° 26'
DRD213-1	16CP	.1257	.0274	+65	15.6	Ext. Flutes Only;
DRD223	16CP	.1288	.0276	-20	17.8	Int. " "
DRD117-3[4]	16F	.1490	.0233	7.5	15.4	Ext. Spiral Flutes

Penetration of optimum wall smooth cone of DRB2 design at zero rev/sec is 18.0 in. of mild steel.

Notes:
1. F refers to chord flutes, machined
   FP " " " " , pressed
   C " " " " , machined
   CP " " " " , pressed
2. A positive value for γ_o means that the cone, viewed from the apex, must be rotated in a clockwise direction at the indicated frequency (rev/sec) in order to exhibit maximum penetration.
3. Root of flute paraliel to inside cone surface.
4. This lot of cones differs from DRD17-6 in that the flutes spiral through 10°, clockwise, from apex to base.

Table VIII
Summary of Serrated Liner Performance
DRB398 Type Cone (See Fig. 4.)

DRB398 type cone, all but one lot of copper cones were made by pressing flutes into drawn blanks. The copper cones of DRD272 No. 1 were machined completely, including flutes and the DRD267 aluminum cones were machined also, but the flutes were pressed. Except where noted wall thickness is essentially constant. Flute depth varies linearly from indicated depth to zero at the theoretical apex of the cone generated by the flute crests. Radius to outside surface at datum for depth and thickness is indicated.

Drawing No.	No. Flutes	Wall Thickness (in.)	Flute Depth (in.)	Radius to Flute Crest (in.)	γ_o	P_{γ_o}	Remarks
DRD272 No. 1	50F	.1615	.0611	1.629	+50	11.4	Ext. Flutes Only
DRD393 item 1	50FP	.1093	.0151	1.617	+60	18.3	"
DRD393 item 2	50FP	.1048	.0129	1.617	+52	20.0	"
DRD267	50FP	.1065	.0089	1.624	+25	20.8	"
DRD267	"	.1074	.0077	1.703	0	8.6	", Alum.
DRD318 item 1	36FP	.0999	.0112	1.583	0	20.0	Int. Flutes Only
DRD319 item 1	45FP	.1021	.0113	1.583	-3	21.1	"
DRD320 item 1	60FP	.1039	.0108	1.583	-3	19.6	"
DRD320 item 2	60FP	.1088	.0211	1.578	-15	18.0	"
DRD320 Item 3	60FP	.1114	.0381	1.567	+3	20.0	"
DRD321 item 1	100FP	.1023	.0098	1.583	-5	20.2	"

Penetration of optimum wall smooth cone of DRD398 design at zero rev/sec is 20.8 in. of mild steel.

Notes:
1. F refers to chord flutes, machined
   FP " " " " , pressed
   C " " " " , machined
   CP " " " " , pressed
2. A positive value for γ_o means that the cone, viewed from the apex, must be rotated in a clockwise direction at the indicated frequency (rev/sec) in order to exhibit maximum penetration.
3. Root of flute parallel to inside cone surface.

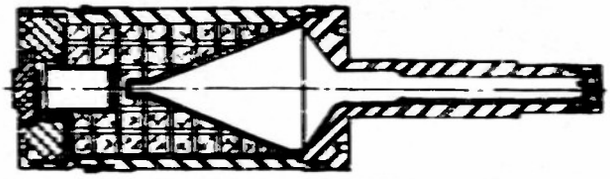
Table IX
Summary of Calculations
Correlation Factor f(N)

$$\gamma_o = \frac{f(N)\,d}{t^2 R} \qquad f(N) = \frac{\gamma_o R t^2}{d}$$

Drawing No	γ_o	$\frac{R}{D}$	t	t^2	$\gamma_o \frac{R}{D} t^2 = f(N)$
DRD267*	0	--	--	--	0
DRD17-6	15	61.9	.1098	.01207	11.20
DRD32-3	35	61.4	.0745	.00550	11.82
DRD34-3	55	24.4	.0845	.00715	9.60
DRD33-3	15	92.9	.1322	.01748	24.3
DRD35-3	15	89.0	.1322	.01748	23.5
DRD161-1	35	118.0	.0835	.00697	28.8
DRD162-2	40	136.0	.0878	.00771	42.0
DRD63-3	65	94.0	.0822	.00676	41.3
DRD63-3	25	90.7	.1312	.01720	39.0
DRD254 Sec. 1*	20	36.1	.1095	.01200	8.65
DRD213-1*	65	55.6	.0483	.00965	14.8
DRD267*	25	182.5	.1009	.01018	46.5
DRD393 item 1*	60	107.0	.0942	.00888	57.0
DRD393 item 2*	52	125.2	.0919	.00844	55.0
DRD272 No. 1	50	26.6	.1004	.01008	18.9

* Flutes are pressed into smooth cones.
d = actual flute depth, inches
t = minimum wall thickness across flute profile, inches
R = radius of cone to crest of flute, inches
d, t, R are all measured at the same datum plane
γ_o = optimum rotational frequency, rev/sec.

Table X
T138E73 Modification



Part	Drawing No.	Material	Weight (lbs)
Band, Rotating	DRB360	Gilding metal, annealed	0.25
Body	DRC321	Steel WD1045	7.41
Cap, Tee	DRA695	Steel WD1030	0.09
Cone	DRD3[illegible]Material	Copper QQ-C-576	0.84
Bushing, Tee Cap	DRA696	Rubber	--
Element, Nose (T222E3)	DRA496		0.03
Pad, shock	DRA461	Felt MIL-F-10954	
Plug, Base (A)	DRA288	Aluminum 24S-T4	0.11
Plug, Base (B)	DRB410	Aluminum 24S-T4	1.03
Ring, "O"	DRA459	Rubber	--
Sleeve, Grommet	DRA492	Nylon FM 3003	--
Strip, Pin	DRA454	Phenolic laminate	--
Tape	DRA627	Viscose Rayon	
Tee	DRC314	Steel WD 1030	5.16
Washer	DRA721	Felt	--
Wire, Fuze Assembly	DRA628	Beryllium Copper #24	--
Element, Base for fuze	DRA579	-----	.36
Charge, H.E.	---	Comp B, Grade I, JAN-C-401	2.27
Total Project Weight (calculated)			17.55

C. G.: 1.29 calibers from base (5.31 inches)

Axial moment of inertia: 43.0 lb-in^2 (nominal)

Transverse moment of inertia: 204.0 lb-in^2 (nominal)

Table XI
Dynamic Penetration Data
Fired Aberdeen Proving Ground 12-9-52

Proj. No.	Muzzle Vel. ft/sec	Striking Vel. ft/sec	Penetration (inches H.A.)	Entrance Hole (inches)	Remarks
--	1558	1452	7.88	4 1/2 x 2 1/4	Angle of plate 63° (obliquity)
889	1571	1464	8.75	4 3/4 x 2 1/4	7-1 1/2" homo armor plates
846	1560	1454	10.00	5 x 3	PA-E 10924 - 1-20 twist
894	1568	1461	--	--	Hit edge of plate
791	1555	1449	6.62	3 3/4 x 1 1/2	Average muzzle spin rate=57 rev/sec
864	1567	1460	7.12	4 1/4 x 2 1/2	
Avg.	1563	1457	8.07		
P50-50	1591	1483	10.00	4 x 2 1/4	Same as above except PA-E-11130
P50-54	1604	1496	10.39	4 1/4 x 1 1/2	
Avg.	1598	1490	10.19		Average muzzle spin rate=58 rev/sec.
340	1632	1523	9.25	5 1/8 x 2 1/2	Angle of plate 62° (obliquity)
321	1639	1530	6.62	4 3/4 x 2 1/2	PA-E 10924 - 1-120 twist.
405	--	--	7.12	3 3/4 x 2 1/2	Average muzzle spin rate=39 rev/sec.
991	1617	1508	6.88	4 1/8 x 2 1/8	
930	1609	1498	9.50	4 1/4 x 2 1/4	
Avg.	1604	1522	7.47		
P50-57	--	--	6.88	4 1/2 x 2	Same as above
P50-52	1646	1536	6.62	4 3/4 x 2 1/2	Except PA-E-11130
P50-58	1648	1548	--	Hit too close to edge	
P50-55	1640	1531	9.25	4 1/4 x 2	Average muzzle spin rate=40rev/sec
P50-56	1620	1511	9.25	4 x 2 1/2	
Avg.	1639	1532	8.00		
Static Test BRL - 60 rev/sec, Green Armor target.					
P50-51			12.94		
P50-53			10.94		
P50-59			13.81		
		Avg.	12.56		

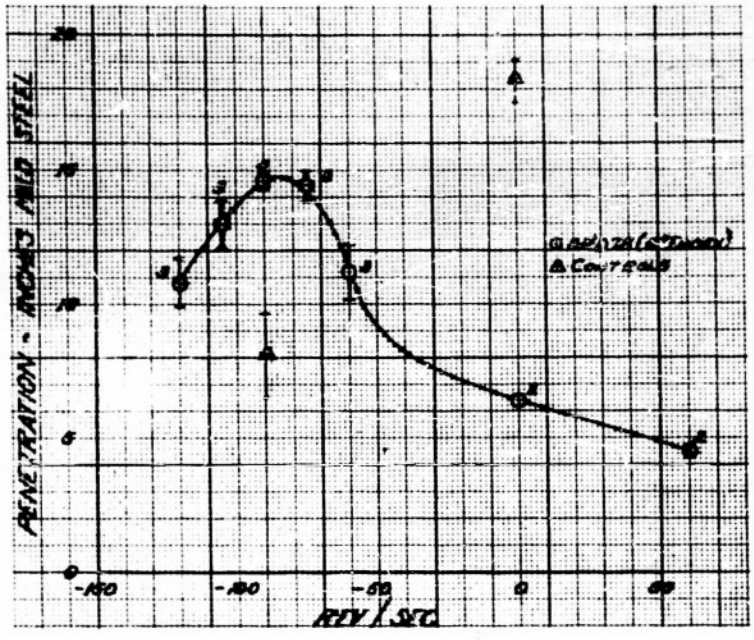


Fig. 5. Penetration Versus Spin Rate.
DRD78 (5-degree Index Angle) Liners.

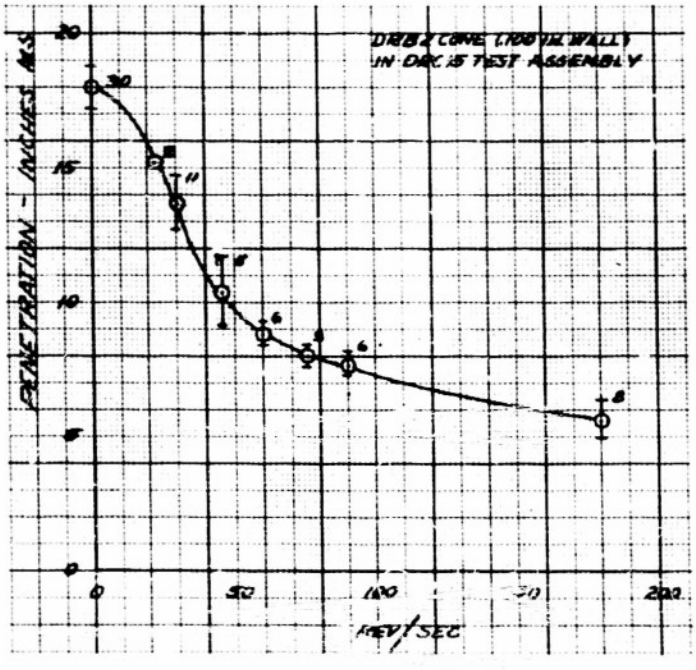


Fig. 6. Penetration Versus Spin Rate.
DRB2 Cones in DRC15 Test Assemblies.

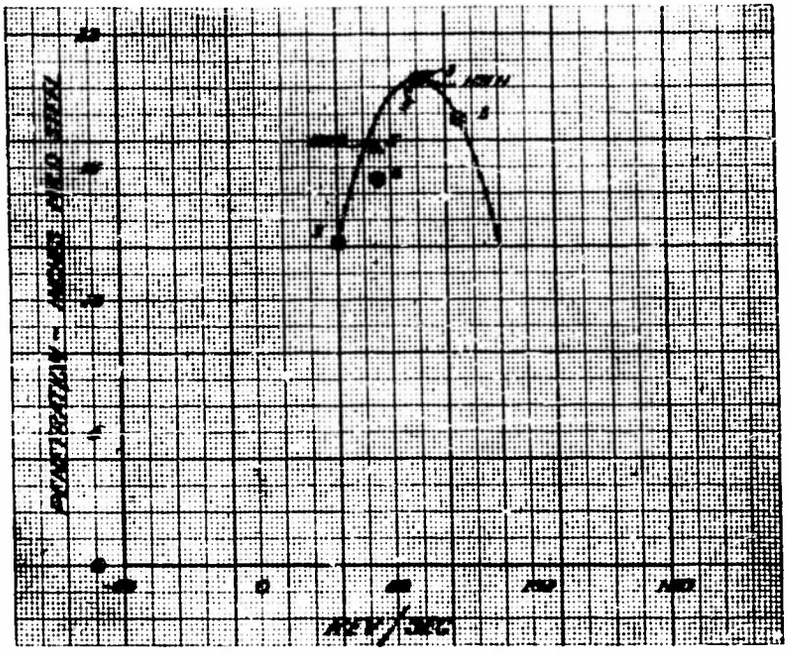


Fig. 7. Penetration Versus Spin Rate.
DRD393 Item 1 Liners.

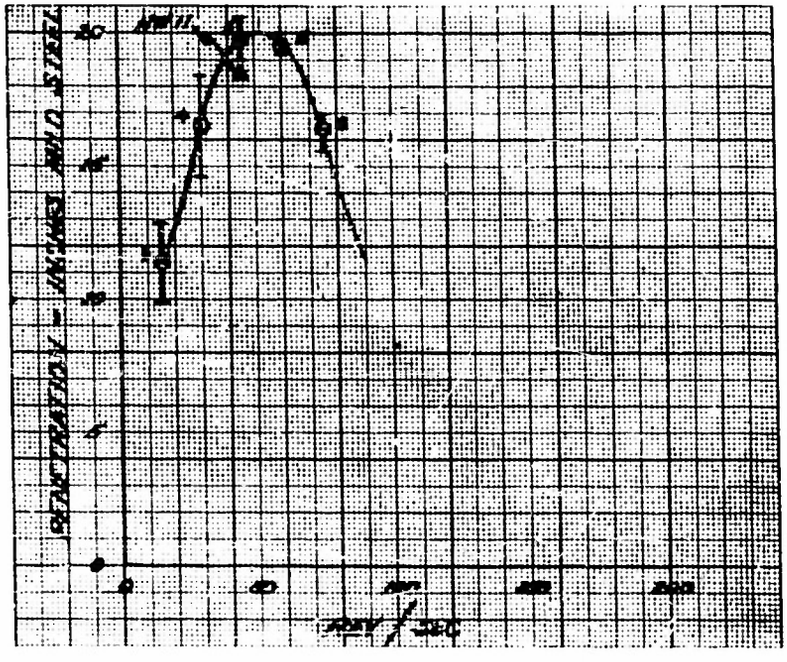


Fig. 8. Penetration Versus Spin Rate.
DRD393 Item 2 Liners.

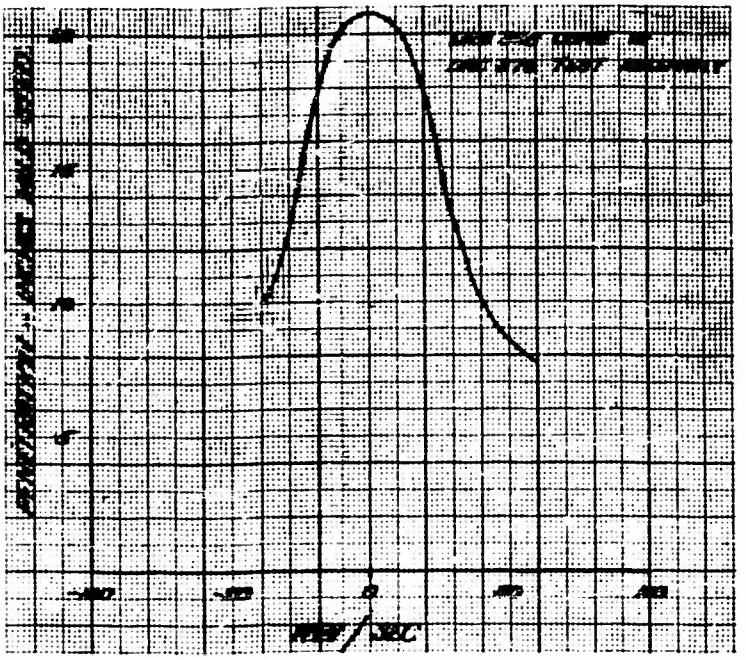


Fig. 9. Penetration Versus Spin Rate.
DRB398 Cones a DRC376 Test Assemblies.

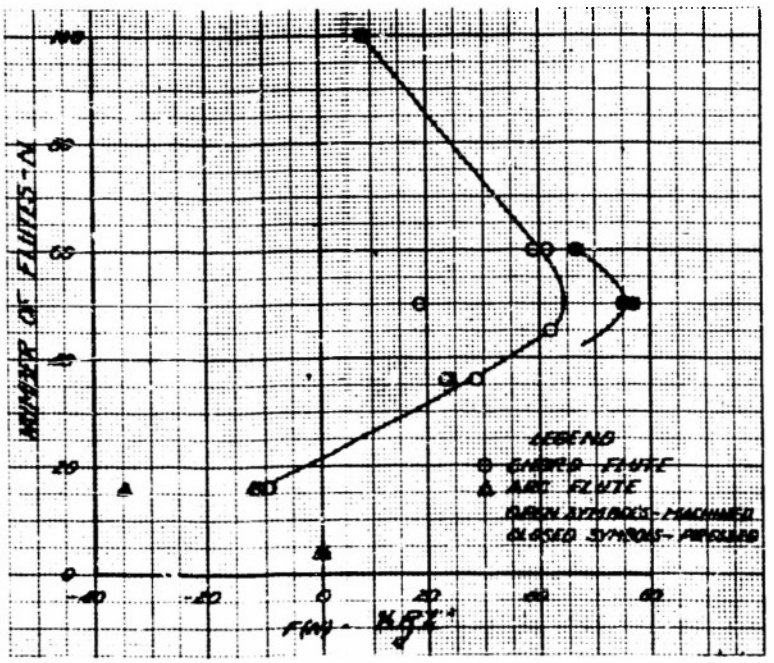


Fig. 10. Correlation Factor Versus Number of Flutes.

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